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MECHANICAL CHARACTERIZATION OF GLASS-BANANA FIBER WITH ALUMINIUM POWDER HYBRID COMPOSITE

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ABSTRACT

In an attempt to utilize the natural resources, this work focuses on fabricating a hybrid composite laminate made up of glass fiber and banana fiber reinforcement and epoxy resin with aluminum powder as the additive filler. Mechanical properties were obtained from tensile, compression and impact tests. Further FEA analysis is carried out using ANSYS to undergo Displacement Deformation Simulation and a Modal Dynamic Test was carried out. The results are compared to the existing conventional composite materials and Finally, the results showed the fabricated hybrid composite has a lower density, a higher ultimate tensile strength, a stronger compression strength, and the decreased deformation length when compared to conventional materials like GFRP and hence have the capability to have a notable use in the aviation industry

***KEYWORDS**: Natural Fiber, Hybrid Composite, Displacement Deformation, Dynamic Testing & Static Analysis*

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Original Article

INTRODUCTION

It is quite clear today, that the impact of the aviation industry on the environment is quite significant and cannot be overlooked. Previously, a lot of importance was placed on the operational phase of the aircraft and the resulting emissions received from this phase. However, new regulations are being made to curb the industry's impact on the environment at the manufacturing stage itself. Studies show that 64% of the aircraft's impact on the surrounding environment is due to the material used to manufacture the structure which is currently Carbon Fiber Reinforced Plastic and aluminum.

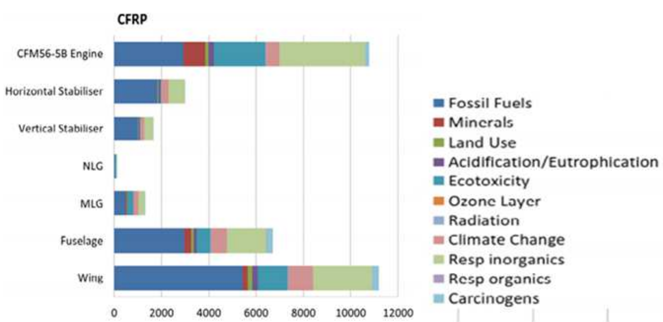

Figure 1

Figure 1 Shows the Overall Impact of CFRP on the Environment due to the Manufacturing of a Single

This work's objective is to analyze the behavior of an alternate composite material that can be used in place of Carbon Fiber on an aircraft structure. After a theoretical study of existing materials, Glass Fiber Reinforced Plastic has been chosen; a material that is commonly used for radom coverings at the leading edge of the aircraft wing and the fin edges due to the material's Electromagnetic Transparency. [4] Carbon fiber conducts electricity, which means it will absorb radar waves transmitted from an antenna which is detrimental to an aircraft structure while Glass fibers have good insulation properties and are transparent to radar waves. Another reason it is used on forward-facing surfaces is the impressive impact tolerance it possesses. Glass fiber has better absorption qualities due to its lower elongation at fracture. The final point to be considered is the fact that carbon is predominantly Anisotropic in nature, so when a carbon fiber is loaded along its length, it breaks easily. However, Glass, being Isotropic in nature, will possess the same break resistance in any direction, which makes glass fiber composite superior in withstanding both arbitrary and impact loads. [4]

The price, density, stiffness and fiber diameter are also key factors in choosing Glass fibers as an alternate material.

The Stiffness factor; Conventional Carbon fiber material is generally three times stiffer than glass fiber. When a material has a high stiffness value, it leads to the wing spar having a lesser capability to flex under a given load. In terms of the price factor; Glass fiber is significantly cheaper compared to carbon fiber. Another factor is Density, Carbon fiber weighs 2.47 kg/m^3 while Glass fiber weighs 2.1 kg/m^3 which are lighter comparatively and better to reduce the overall weight of an aircraft structure. A final factor is Fiber diameter, Glass fibers are much thicker than carbon fibers, which makes them perform better when exposed to compression loads.

Natural fibers have recently been added to composite materials because of the fact that they are biodegradable, recyclable, renewable, and are relatively cheaper in cost when compared to other conventional composite materials. Banana fibers are renewable, have a lighter density and in a country like India, are easily available. Banana fibers also have an impressive tensile strength as an individual fiber and can act as strength, adding agents when added to composite structures. With these appealing properties, banana fiber is an environmentally sustainable alternative that can be used instead of conventional aircraft structural composite materials. [7]

In order to increase the high tensile strength consumed by CFRP, an advanced GFRP laminate has been fabricated with alternating layers of banana fiber, a widely used natural fiber in India. Aluminum powder which is said to be a strength, adding agent is continuously stirred with epoxy resin, which shows an additional rise in the abrasion resistance, coated surface hardness and also improves the composite material's resistance to a great extent. [8]

This epoxy resin can be used as a base for subsequent fabrication of laminate. Aluminum possesses low weight, excellent corrosion resistance, high strength, and electrical conductivity. The main objective of combining aluminum powder with the epoxy resin is to improve the composite material's properties such as its hardness and reduce the brittle nature of the composite material. Aluminum powder which is generally found to have a particle size of 0.75-80 micron and hence is found to give a high impact on the mechanical properties of the material. [3]

EXPERIMENTAL WORK

Method of Preparation of the First GFRP Laminate

A GFRP sheet is taken and placed on a waxed glass paper. A mixture of epoxy resin (300 ml) (LY556) and hardener (30 ml) HY957 at a ratio 10:1 by the weight of resin is supplemented to the epoxy and this mixture is stirred

manually for about ten minutes in a proper manner and on account of this exothermic reaction is about to start. The mixture is spread evenly onto the glass fiber sheet when another glass fiber sheet is placed above it at the same orientation and impregnated onto the resin-hardener mixture. This process is repeated for five more layers and the GFRP laminate is fabricated.

Figure 2

Figure 2 shows the initial materials and the method of preparation of the GFRP laminate.

Method of Preparation of Hybrid Composite of GFRP, Banana Fiber, and Aluminum Reinforced Epoxy

A GFRP sheet is taken and placed on a waxed glass paper. An epoxy resin (400 ml) (LY556) and hardener (40 ml) HY957 at a ratio 10:1 by weight of the resin is added to the epoxy and this mixture is stirred continuously for ten minutes and in this case, the exothermic reaction is stimulated. The aluminum powder is added to the epoxy resin, mixed continuously using a stirrer, the hardener is then added to the aluminum epoxy mixture. Based on exothermic reactions rousing of the mixture continues for a period of time and spread evenly onto the glass fiber sheet. 5 g of chopped banana fiber is measured and sprayed onto the above spread mixture. This process is repeated for five more layers and the GFRP-Banana fiber Aluminum reinforced hybrid composite is made. [2]

Figure 3

Figure 3 Shows the Initial Materials and Fabrication Process for the Hybrid Composite

Table 1 Indicates Significant Values for the Laminates Formed

Table 1

Number of layers	12
Overall weight	322g
Weight of Banana Fibre	5g
% of Aluminium Powder added	6.12%
Weight of Aluminium added in epoxy	25g
Volume of epoxy	400 ml
Temperature observed	22°C
Thickness of the laminate	3.4 mm

TESTING

After the specimens are cut in accordance with ASTM standards, (Table 2) into 9 specimens, in each category, they are subjected to mechanical tests. The first category being normal GFRP, the second, Glass- Banana fiber composite with aluminum additive.

Table 2 Represents the Specimen Dimensions for the Conducted Mechanical Tests According to the ASTM Standards

Table 2

Dimensions	
Tensile test	250x25x3.4mm
Compression test	250x25x3.4mm
Impact test	80x10x3.4mm

Tensile Test (D3039)

A total of four Specimens is prepared for the test. These specimens have been separated into two different groups, each consisting two specimens. The first two specimens are normal GFRP, the second group is the Hybrid Glass- Banana fiber composite with aluminum additive. The tensile test fixtures were then fitted in the UTM machine (Figure 4). To measure the force required to break a polymer composite. The specimen tends to stretch or elongate to that breaking point. The specimens were then loaded turn by turn, such that a span length of 250 mm was maintained for each specimen. The mechanical test was carried out and the Load vs. Displacement and the Stress vs. Strain graphs were plotted.

Figure 4

Figure 4: Shows the Tensile Test for the given Hybrid Composite

Compression Test (D34310)

The compressive strength of GFRP and the hybrid composite were estimated using a compression test which is a 3-point bend test, which generally promotes failure by inter-laminar shear. A load of 0.6 KN was applied to the specimen to be tested. A total of four mechanical tests was performed according to ASTM standards and the respective mechanical properties determined. The material's ability to resist deformation under load is found and the Load vs. Displacement and the Stress vs. Strain graphs were plotted.

Figure 5

Figure 5: Shows the Experimental Set up of the Compression Test

Impact Test

The method is also used to investigate the behavior of composites under impact conditions for estimating the relative brittleness or toughness of specimens, especially for comparison. A total of 6 Specimens is prepared for the test. These specimens have been separated into two different groups, each consisting three specimens of 80x10x304 mm dimensions. The first three specimens are normal GFRP and the second group is the hybrid composite and the impact test which is a single point testing that measures the resistance of a material to impact. [10] It derives the kinetic energy required to initiate fracture and continue it until broken and computes the amount of energy the material can absorb in Joules.

Figure 6

Figure 6: Shows the Experimental Set Up of the Impact Test on the Hybrid Composite

AIRCRAFT WING DESIGN ON CATIA

To analyze how the fabricated composite material would behave as a component of an aircraft, an Aircraft wing has been designed to carry out the static and dynamic analysis in ANSYS.

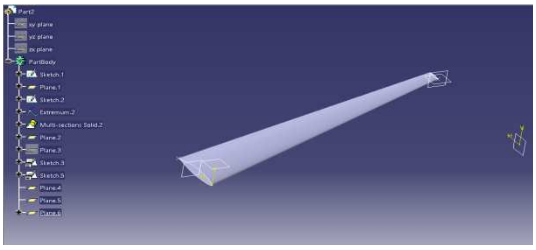

Figure 7

Figure 2 shows the wing designed on CATIA for the application of the hybrid composite that will be fabricated.

Table 3

DIMENSIONS	
Length	60 m
Wing Span	68.4 m
Wing Area	554 m^2
Wing Sweep	37.5^0
Aspect Ratio	8.45
Airfoil	BAC463

Table 3 indicates the dimensions of the designed wing structure.

STATIC AND DYNAMIC TESTING ON ANSYS

Static Testing on ANSYS

A static analysis calculates the effects of steady loading conditions on a structure and ignores loads caused by time-varying loads such as impact and damping loads. The structure's response to the load applied varies slowly with respect to time. [9] For this experiment, we consider externally applying forces and pressures acting uniformly on the wing

structure which is supported at one end.

The model designed on CATIA is imported and the necessary boundary conditions applied, which then results in the values of various static structural parameters such as; Directional Deformation – X -Axis, Directional Deformation – Y -Axis, Directional Deformation – Z -Axis, Equivalent Elastic Strain max, Equivalent Stress max, Elastic Strain Intensity, Normal Elastic Intensity max, Normal Stress max, Shear Elastic Strain, Stress Intensity, Shear Stress and Total Deformation.

Dynamic Analysis

Modal analysis is the study of the dynamic properties of systems in the frequency domain. A typical example would be testing structures under vibrational excitation. It entails the analysis of the dynamic response of structures under excitation and is the study of the dynamic properties of systems in the frequency domain. A typical example would be testing structures under vibrational excitation. A dynamic load is one which changes with time relatively quicker in comparison to the structure's natural frequency. If it changes slowly, the structure's response may be determined by static analysis, but if it varies quickly, the response must be determined by a dynamic analysis. The distinction between a dynamic and static analysis is based on whether the applied load has enough acceleration when compared to the natural frequency of the structure. When the load is applied slowly, the inertia forces can be ignored and the analysis is termed as 'static analysis.'[9]

RESULTS

Mechanical Properties

Table 6.1

Contents	CFRP	GFRP	Banana Fiber	Aluminium	Hyb.Composite (GFRP+Banana+Al Filler)
Ultimate tensile strength (MPa)	1600	181	540	90	268
Compression Strength (MPa)	9	5	40	70	6
Energy Absorption Joules)	11.33	4.67	2.8	7	7.33

Table 6.1 indicates the results of the mechanical tests on the two fabricated composites with a comparison of standard values of CFRP, Banana fiber, and Aluminium.

Static Analysis Results

Table 6.2

Directional Deformation – X Axis	0.11231 mm
Directional Deformation – Y Axis	92.267 mm
Directional Deformation – Z Axis	228.88 mm
Equivalent Elastic Strain max	0.00094 mm
Equivalent Stress max	9.728 Mpa
Elastic Strain Intensity	0.0070315 mm
Normal Elastic Intensity max	4.01e-5 mm
Normal Stress max	6.5755 Mpa
Shear Elastic Strain	0.0002303 Mpa
Stress Intensity	9.7822 MPa
Shear Stress	0.1602 Mpa
Total Deformation	546.27 mm

Table 6.2 indicates the results of the static analysis test on ANSYS

Boundary Conditions for Modal Analysis

Table 6.3

Material	Young's Modulus (MPa)	Poisson's Ratio	Density (kg/m^3)
Hybrid Composite	183.5	0.319	2215

Modal Dynamic Analysis Results for Hybrid Composite

Table 6.4

Number of Modes	Frequency
1	1.1724
2	3.7186
3	6.5244
4	8.2982
5	16.3356
6	20.1364

The above table indicates the **Natural Frequency** value for each mode of total deformation in a hybrid composite.

CONCLUSIONS

It has been observed that the hybrid composite fabricated has a lower density, a higher ultimate tensile strength, a stronger compression strength, and the least deformation length when compared to conventional materials like GFRP and hence have an impressive use in the aviation industry. From the analysis done, we have found that the fabricated Hybrid Composite has 54% better resistance to deformation when compared to the standard GFRP, has 48% higher Ultimate

Tensile Strength and 20% higher Compression Strength than the standard GFRP fabricated**.** India is popularly known as one of the largest banana producing countries in the world, the diverse implementations of Banana fiber in composite structures can be further evolved if a suitable cost-effective method of fiber separation is developed which would increase its industrial application to a far more eminent extent. Thus we conclude that a systematic and persistent research in this field of natural fibers incorporated in composite structures will significantly improve the environmental impact of the aviation industry and aid in making the industry far more sustainable than it currently is.

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